Goddard

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO
ATTN OF: GP

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U. S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code USI, the attached NASA-owned U. S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U. S. Patent No. : 3,571,656

Government or Corporate Employee : Weston Instruments EMR Division College Park, Md.

Supplementary Corporate Source (if applicable) :

NASA Patent Case No. : XGS-11177

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:
Yes ☑ No ☐
Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of Column No. 1 of the Specification, following the words ". . . with respect to an invention of . . ."

Elizabeth A. Carter

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Enclosure
Copy of Patent cited above

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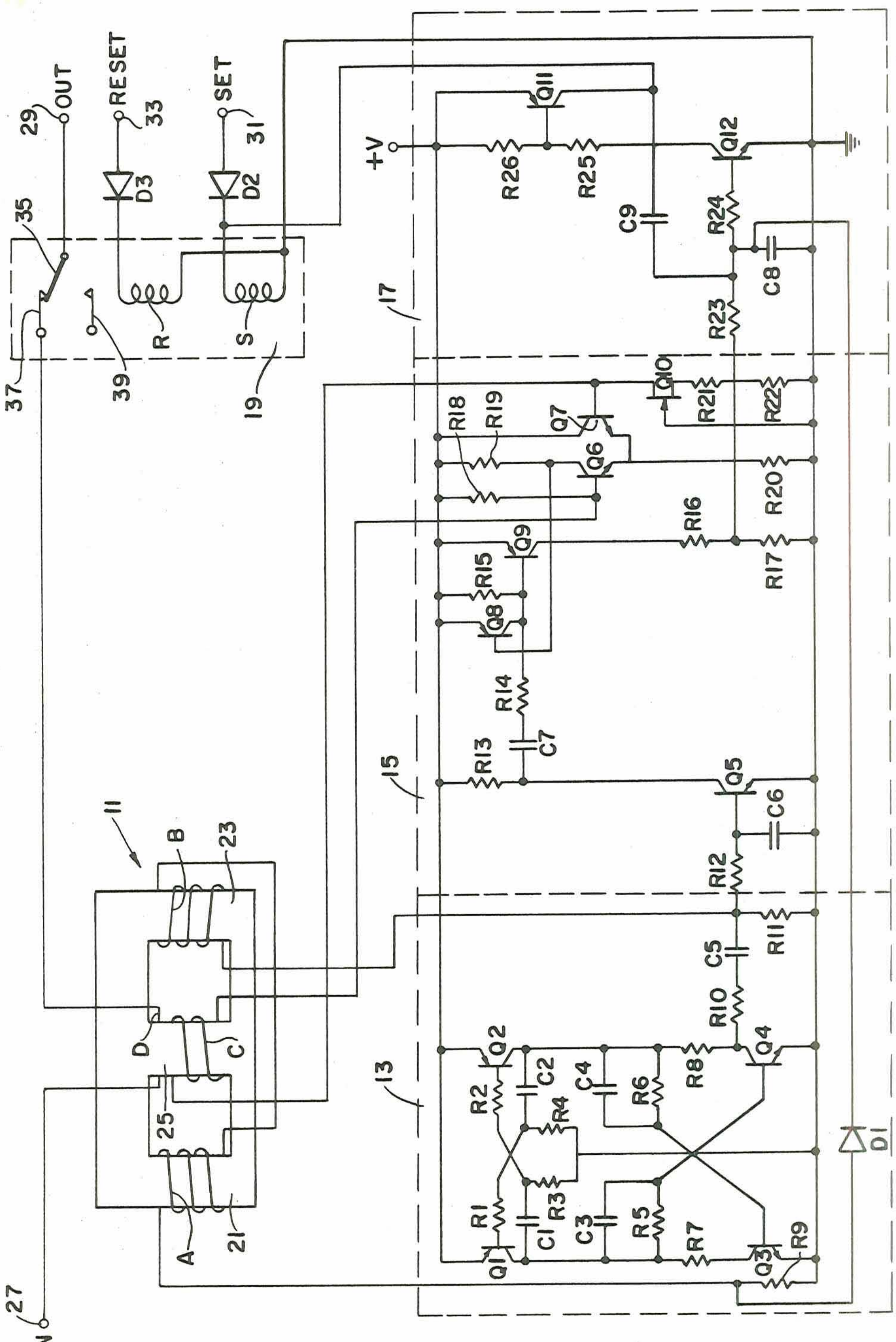

FIG. 1.

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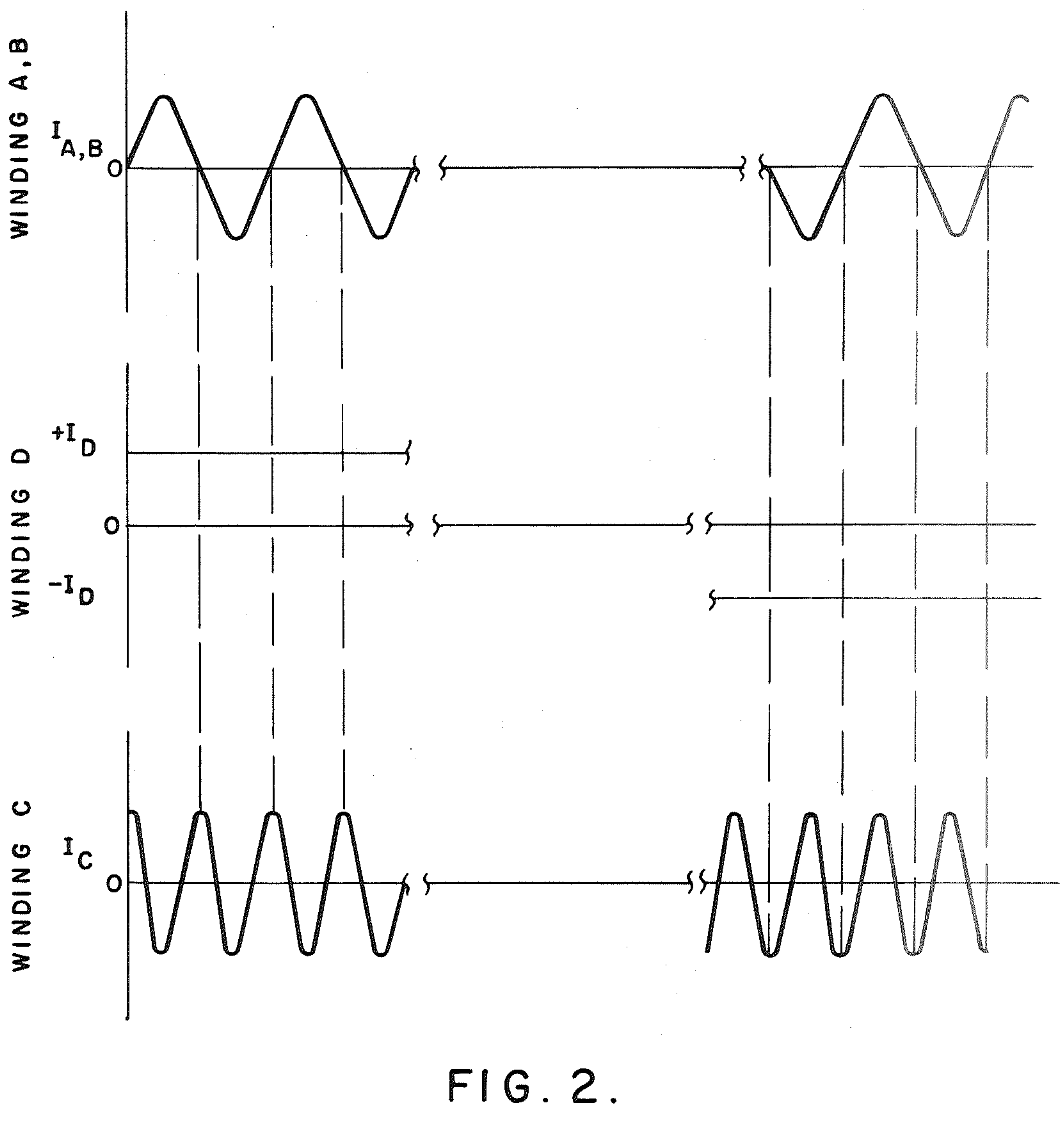

FIG. 2.

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United States Patent

[11] 3,571,656

[72] Inventors T. O. Paine, Administrator of the National Aeronautics and Space Administration with respect to an invention of, Roland E. Genter, Falls Church, Va.

[21] Appl. No. 828,921
[22] Filed May 29, 1969
[45] Patented Mar. 23, 1971

[54] **ELECTRONICALLY RESETTABLE FUSE**
8 Claims, 2 Drawing Figs.

[52] U.S. Cl. 317/9, 317/33
[51] Int. Cl. H02h 3/08, H02h 7/26
[50] Field of Search .... 323/89 (orig), 89 (XR), 89 (X); 317/27, 33, 43, 48, 9, 39, 60; 336/155

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UNITED STATES PATENTS

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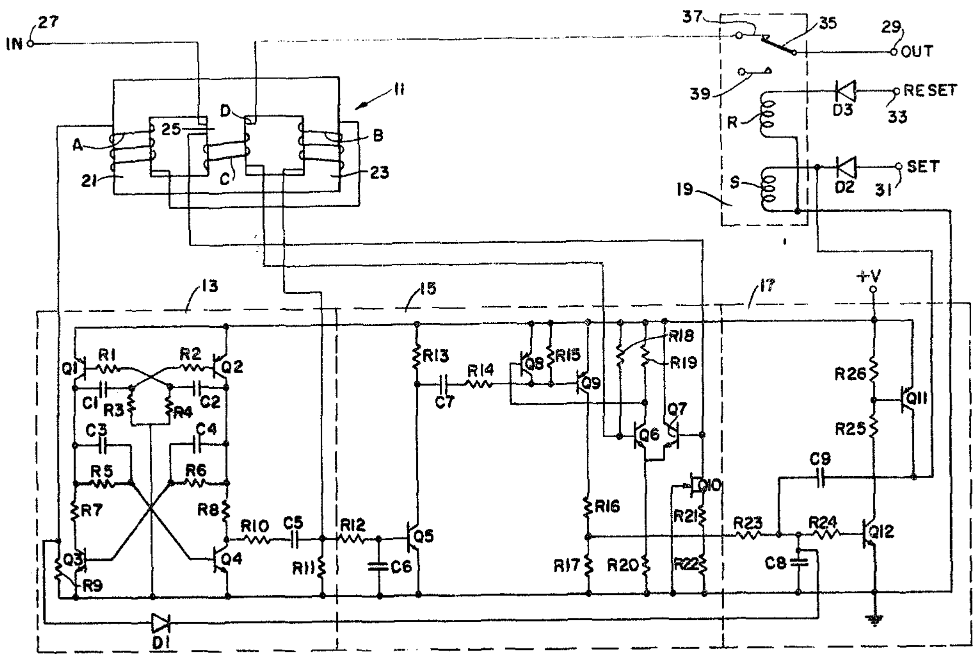
ABSTRACT: An electronically resettable fuse includes a saturable core current sensing transformer having two outside legs and a center leg. An oscillator is connected to balanced oscillator windings wound about the outside legs so as to produce an AC flux which saturates the outside magnetic path at waveform peak points. A DC current whose magnitude is to be sensed is passed through a control winding wound about the center leg, and produces a DC flux in the center leg which completes its loop through the two outside legs, only during intervals when the outside path is unsaturated. This completion occurs twice per cycle and is sensed by a sense winding also wound about the center leg. When the current in the control winding surpasses a bias level, the induced DC flux direction reverses and a 180° phase shift across the sense winding occurs. This phase reversal is sensed by a phase detector and utilized to open relay contacts connected to the control winding. External means for resetting the relay from a remote location are also provided.



ELECTRONICALLY RESETTABLE FUSE

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of section 305 of the National Aeronautics and Space Act of 1958, Public Law 85—568 (72 Stat. 435; 42 U.S.C. 2457).

BACKGROUND OF THE INVENTION

Various types of apparatus for fusing electronic circuits are well known. They vary from simple fuses which are destroyed when an excessive current condition occurs to complex fuses which "drop out" and reclose through several cycles before completely locking out when an excessive current condition occurs.

In the past, spacecraft experiments have been reluctant to allow fuses in the power line to their experiments for fear that a small surge in current might cause a fuse to blow and permanently kill their experiment. Moreover, it is difficult to determine the precise amount of current necessary to blow a fuse because once the precise amount of current is determined, the fuse is destroyed and, hence, must be discarded. While recycle type of fuse systems could be used, they are not satisfactory because they are overly complex and bulky. Consequently, there is need for a fuse that will blow when an excessive current occurs but can be reset from a remote source, such as by a pulse generated by a ground station and transmitted to a spacecraft, for example.

If the fuse is to be utilized on a spacecraft, it will be appreciated that it must meet certain other requirements. For example, the fuse must have a minimum voltage drop, minimum power requirements, small weight and small volume. In addition, it must operate at relatively low ampere ratings such as one-sixteenth or one-eighth amp., and incorporate slow blow characteristics with inverse time delay for transient loads. Moreover, the fuse must be operable under fluctuating voltage conditions without blowing if the load is driven from a fluctuating voltage source.

Therefore, it is an object of this invention to provide a new and improved fuse.

It is a further object of this invention to provide an electronic fuse that is resettable.

It is a still further object of this invention to provide an electronically resettable fuse that can be electronically reset from a remote source.

It is still a further object of this invention to provide an electronically resettable fuse suitable for use on a spacecraft that has a minimum voltage drop, power requirement weight and volume, and operates at a low ampere value over a relatively wide voltage range.

SUMMARY OF THE INVENTION

In accordance with the principle of this invention an electronically resettable fuse is provided. The fuse includes a saturable transformer having two outside legs and a center leg. Balanced oscillator windings are wound around the outside legs and connected to an oscillator so that the outside path is saturated at waveform peak points. The center leg includes a first winding connected so as to sense current flow to a load and a second winding connected to a phase detector. The phase detector receives a second signal from the oscillator. In addition, the second winding is biased to a predetermined level. In operation, because the oscillator windings are balanced and in phase, the AC flux developed by these windings cancel in the center leg. When a DC current is passed through the first winding, a DC flux is produced in the center leg which completes its path through the outside legs. Due to the saturation effect of the AC excitation, the DC flux path is only completed during periods of unsaturation in the outside legs. This completion occurs at twice the excitation rate. Because the second winding is biased, the flux induced by the first winding will exceed the flux induced by the second winding at a predetermined level. When this level is reached, the phase of the AC flux induced in the second winding reverses. This phase reversal is sensed by the phase detector which generates a control signal that is sensed by a relay driver circuit. The relay driver circuit operates a relay that has contacts in the power line circuit to the load.

In accordance with a further principle of this invention, the oscillator, phase detector and relay driver circuit are formed of solid-state components which have low power consumption. Moreover, the relay is a latching relay that only draws power when it receives a control pulse.

In accordance with still further principle of this invention, means are provided for externally resetting the relay from a contact open condition to a contact closed condition. Moreover, external override means are provided for changing the relay from its normally contact closed condition.

It will be appreciated by those skilled in the art and others from the foregoing brief summary that the invention provides an electronically resettable fuse that senses the DC current flow from a DC source to a load. When the DC current flow exceeds a predetermined level, a phase detector senses a phase reversal and generates a signal that causes the circuit between the DC source and the DC load to open. The invention operates when a gradually increasing DC current change occurs or when an instantaneous current change occurs. Moreover, the invention operates at low current levels and over widely fluctuating voltage ranges such as from 30 to 70 volts, for example. Finally, the invention is suitable for use on a space vehicle because it can be reset from a remote location, such as a telemetered pulse from a ground station.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing objects and many of the attendant advantages of this invention will become more readily appreciated as the same becomes better understood by reference to the following detailed description when taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a schematic diagram illustrating a preferred embodiment of the invention; and

FIG. 2 is a waveform diagram illustrating the waveform of the currents in the various windings of the transformer illustrated in FIG. 1 for various current conditions.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates a preferred embodiment of the invention and generally comprises: a current sensing transformer 11; an oscillator 13; a phase detector 15; a relay drive circuit 17; and, a latching relay 19. The current sensing transformer 11 includes a saturable core having two outside legs 21 and 23 and a center leg 25. Balanced oscillator windings A and B are wound about the outside legs 21 and 23; a sense winding C is wound about the center leg; and, a control winding D is also wound about the center leg 25. The control winding D is connected in circuit between an input terminal 27 and an output terminal 29.

The balanced oscillator windings A and B are connected in series across the output of the oscillator 13. Because the oscillator windings are balanced and in phase, the AC flux developed by these windings cancels in the center leg 25. The purpose of the AC excitation is to produce an AC flux which saturates the magnetic path through the outside legs at waveform peak points. Assuming that a DC current is passing through the control winding D, a DC flux is produced in the center leg 25 which completes its loop through the two outside legs 21 and 23. Due to the AC excitation previously described, the outside path cyclically saturates and unsaturates. Because of this cyclic operation, the DC flux path is completed only during intervals when the outside path is unsaturated. When the path through the outside leg is saturated it acts essentially as an open circuit for the DC flux. Because the outside path is moved into and out of saturation twice per excitation cycle, the DC flux path is completed twice per excitation cycle. Consequently, the AC voltage that appears across the sense winding C is twice the frequency of the oscillator output.

FIG. 2 illustrates idealized waveforms for the current flowing through the various windings of the current sensing transformer 11 under different conditions. More specifically the first waveform line illustrates the waveform of the current flow through windings A and B; the second waveform line illustrates the waveform of the current flow through the control winding D; and the third waveform line illustrates the waveform of the current flow through the sense winding C. The leftmost portion of FIG. 2 illustrates the waveforms for a positive current flow through control winding D; the center of FIG. 2 illustrates the waveforms when zero current is flowing through control winding D; and, the rightmost portion illustrates the waveforms when a negative current flows through control winding D. It will be noted from viewing FIG. 2 that the induced DC flux direction reverses when the current through the control winding reverses. This reversal creates a 180° phase shift in the AC induced in the sense winding. Preferably, the turns ratio between the control and sense windings is rather high, such as 1:1000, for example. As hereinbefore described in actual use, a DC bias current is passed through the sense winding in the direction of the flux induced by a positive current flow through the control winding D. When biased in this manner, the current flow through the control winding must surpass a predetermined level before phase reversal occurs. As also hereinafter described, it is this phase reversal that is sensed to control the operation of the latching relay 19.

The oscillator 13 illustrated in FIG. 1 comprises: two PNP transistors designated Q1 and Q2; to NPN transistors designated Q3 and Q4; a diode designated D1; eleven resistors designated R1, R2, R3, R4, R5, R6, R7, R8, R9, R10 and R11; and, five capacitors designated C1, C2, C3, C4 and C5.

The emitters of Q1 and Q2 are connected together and to a voltage source designated +V. The base of Q1 is connected through R1 in series with C2 to the collector of Q2 and the base of Q2 is connected through R2 in series with C1 to collector Q1. The junction between R1 and C2 is connected through R4 in series with R3 to the junction between R2 and C1. The junction between R3 and R4 is connected to ground.

The collector of Q1 is connected through R7 to the collector of Q3 and the collector of Q2 is connected through R8 to the collector of Q4. The collector of Q1 is also connected through C3 in parallel with R5 to the base of Q4. The collector of Q2 is also connected through C4 in parallel with R6 to the base of Q3. The emitters of Q3 and Q4 are connected together and to ground. The emitter of Q3 is also connected through R9 to the anode of D1. The junction between R9 and D1 is connected to one end of winding A of the current sensing transformer 11. The collector of Q4 is connected through R10 in series with C5 and R11 to ground. The junction between C5 and R11 is connected to one end of winding B of current sensing transformer 11. The other ends of winding A and B are connected together.

From the foregoing description, it will be appreciated by those skilled in the art and others that the oscillator 13 is a complementary transistor oscillator well known in the art. It has particular advantages for use with this invention because of its low power requirement and low output impedance. The output is capacitively coupled through C5 to the balanced oscillator windings A and B of the current sensing transformer 11. In addition, as is hereinafter described, the output is capacitively coupled to the phase detector 15. As is well known, the complementary transistors of the oscillator 13 alternately switch on and off thereby generating a square wave signal at a frequency determined by the specific value of the components used. However, any AC generator which has a waveform which results in saturation in the outer legs of the transformer for a portion of each half of the AC cycle will satisfy the drive requirements for the transformer.

The phase detector 15 illustrated in FIG. 1 comprises: three NPN transistors designated Q5, Q6 and Q7; two PNP transistors designated Q8 and Q9; a field effect transistor designated Q10; eleven resistors designated R12, R13, R14, R15, R16, R17, R18, R19, R20, R21 and R22; and, two capacitors designated C6 and C7. The junction between C5 and R11 of the oscillator 13 is connected through R12 to the base of Q5. The base of Q5 is also connected through C6 to ground and the emitter of Q5 is connected directly to ground. The collector of Q5 is connected through R13 to +V.

The junction between R13 and the collector of Q5 is connected through C7 in series with R14 to the collector of Q8 and to the base of Q9. The emitters of Q8 and Q9 are connected to +V. The base of Q9 is connected through R15 to +V and the base of Q8 is connected to the collector of Q6. The collector of Q9 is connected through R16 in series with R17 to ground.

The base of Q6 is connected to one end of winding C of the current sensing transformer 11 and through R18 to +V. The collector of Q6 is connected through R19 and +V and, the emitter of Q6 is connected to the emitter of Q7 and through R20 to ground. The collector of Q7 is connected to +V and the base of Q7 is connected to the other end of sense winding C of the current sensing transformer 11. The base of Q7 is also connected to the source of Q10. The gate of Q10 is connected to ground. And, the drain of Q10 is connected through R21 in series with R22 to ground.

The phase detector 15 detects when a phase reversal occurs in the signal detected by the sense winding C. In operation, a differential amplifier consisting of transistors Q6 and Q7 and their associated resistors amplifies the signal sensed by sense winding C. The amplified signal is essentially a square wave and is applied to Q8. Q8 either inhibits the signal or allows a negative spike to pass through C7 to the base of Q9. The negative spike turns on Q9. The phase relationship between the signal sensed by sense winding C and the signal generated by oscillator 13 is such that under normal operating conditions Q8 is on when the negative pulse through C7 occurs, and, thereby prevents Q9 from turning on. However, if the bias current point for the sense winding determined by the voltage passing from +V through R18, sense winding C, Q10 and R21 and R22 to ground is exceeded the phase of the sense winding signal shifts 180° as hereinbefore described. When the phase of the sense winding signal shifts 180° Q8 is off when the pulse through C7 occurs and, hence, Q9 is turned on. When Q9 is on and a spike occurs, a pulse is applied to the relay driver circuit 17 which, is hereinafter described, energizes latching relay 19.

The relay drive circuit 17 illustrated in FIG. 1 comprises: a PNP transistor designated Q11; and NPN transistor designated Q12; four resistors designated R23, R24, R25 and R26; and, two capacitors designated C8 and C9. The junction between R16 and R17 of the phase detector 15 is connected through R23 and R24 to the base of Q12. The emitter of Q12 is connected to ground. The junction between R23 and R24 is connected through C8 to ground and to the cathode of D1 of the oscillator 13. The collector of Q12 is connected through R25 in series with R26 to +V. The junction between R23 and R24 is also connected through C9 to the collector of Q11. The junction between R25 and R26 is connected to the base of Q11 and the emitter of Q11 is connected to +V.

The relay drive circuit has delay characteristics which are controlled by the values of R16, R17 and C8. That is, if the series of pulses from Q9 are present for a sufficient period of time, depending on the values of these components, the voltage on C8 will reach the turn on threshold level of Q12. When Q12 turns on, it turns on Q11 which as hereinafter described applies a voltage to the set coil of the latching relay 19. If the pulses from Q9 are present for an insufficient period of time Q12 and, hence, Q11 are not turned on. R9 and D1 of the oscillator circuit 13 are contained in the overall system to assure that the relay drive circuit reacts to a very high current overload which could be sufficient to saturate the magnetic core of the current sensing transformer 11.

The latching relay 19 illustrated in FIG. 1 comprises: a set coil designated S; a reset coil designated R; and a set of relay contacts. One side of the set coil S is connected to ground and the other side is connected to the collector of Q11, hence, Q11 is connected so that it energizes or drives S. The same side of S that is the collector of Q11 is connected to the cathode of a diode designated D2. The anode of D2 is connected to a set terminal 31 so that an external set signal can be applied to the set coil S, if desired.

One side of the reset coil R is connected to ground and the other side is connected to the cathode of a diode designated D3. The anode of D3 is connected to a reset terminal 33 so that an external reset signal can be applied to the reset coil.

The contacts of the latching relay 19 include a moveable contact element 35 and upper and lower contact points 37 and 39. The moveable contact element 35 is connected to the output terminal 29 and is moveable so as to come in contact with the upper and lower contact points 37 and 39. The upper contact point 37 is connected through the control winding D of the current sensing transformer 11 to the input terminal 27. The lower contact point 39 is unconnected. Normally, the moveable contact element 35 is in contact with the upper contact point 37 so that current can flow from the input terminal to the output terminal. When a current surge occurs, the current sensing transformer 11 senses the surge and the previously described phase reversal occurs. The phase reversal is sensed by the phase detector and a pulse is applied to the relay driver circuit 17, which after a suitable delay, applies a pulse to the reset coil S. This latter pulse causes the moveable contact element 35 to move out of contact with the upper contact point 37 and move into contact with the lower contact point 39. Hence, the circuit between the input terminal 27 and the output terminal 29 is broken. Thereafter, when a reset pulse is applied to the reset terminal 33 the moveable contact element reverts to its prior or normal position and the circuit between the input terminal 27 and the output terminal 29 is again completed. The set terminal 31 allows an external pulse to be utilized to open circuit the system.

It will be appreciated from the foregoing description that an electronically resettable fuse is provided by the invention. Regardless of whether the excessive current occurs slowly or rapidly, the fuse circuit operates to sense when the current from the input terminal to the output terminal surpasses a predetermined point. When this condition occurs, a phase reversal in the sense winding is detected by a phase detector and a pulse is applied to a relay drive circuit. The relay drive circuit then activates the set coil of a relay to open the circuit between the source and the load. Means are provided for resetting the relay from an external source such as via telemetry from a ground station. In addition means are provided for remotely opening the circuit between the source and the load.

It will be appreciated by those skilled in the art and others that only a preferred embodiment of the invention has been described and that other embodiments fall within the scope of the invention.

I claim:

1. An electronically resettable fuse comprising:
   a saturable core current sensing transformer having one winding connected so as to detect the current flow in a DC current flow path;
   oscillator connected to said current sensing transformer to drive it in a balanced manner causing saturation of a predetermined magnetic path at waveform peak points;
   a phase detector having one input connected to said oscillator and a second input connected to a sense winding wound about said current sensing transformer for detecting a phase reversal between said two inputs and for generating an output when said phase reversal occurs; and
   circuit opening means connected to said phase detector for open circuiting said DC current flow path when said phase detector generates an output signal.

2. An electronically resettable fuse as claimed in claim 1, wherein said current sensing transformer include two outside legs and a center leg, said outside legs including balance windings connected to said oscillator; said winding connected so as to detect a current flow in a DC current flow path and said sense winding being both wound about said center leg.

3. An electronically resettable fuse as claimed in claim 2, wherein said open circuit means comprises a relay having a set winding connected to the output of said phase detector.

4. An electronically resettable fuse as claimed in claim 3, wherein said relay includes a reset coil adapted to receive an external reset signal.

5. An electronically resettable fuse as claimed in claim 4, wherein said phase detector applies a bias current to said sense winding.

6. An electronically resettable fuse as claimed in claim 5, including a relay drive circuit connected between the output of said phase detector and the set coil of said relay.

7. An electronically resettable fuse as claimed in claim 6, wherein said relay drive circuit includes time delay components.

8. An electronically resettable fuse as claimed in claim 7, wherein said oscillator is a complementary transformer oscillator.